Market Power in Electricity Markets:
Beyond Concentration Measures

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Abstract

The wave of electricity market restructuring both within the United States and worldwide has brought the issue of horizontal market power to the forefront. Traditionally, estimation and prediction of market power has heavily relied on concentration measures. In this paper, we discuss the weaknesses of concentration measures as a viable measure of market power in the electricity industry, while proposing an alternative method based on market simulations and the use of plant level data. We discuss results from previous studies the authors have performed, and present new results that allow for the detection of threshold demand levels where market power is likely to be a problem. In addition, we analyze the impact the recently proposed divestitures in the California electricity market will have on estimated market power. We close with a discussion of the policy implications of the results.

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1. Introduction

Horizontal market power is one of the central issues surrounding electricity industry restructuring in the United States. There has been a great deal of discussion recently about how to best analyze the potential for market power in restructured electricity markets. Indeed, recent efforts by the Federal Energy Regulatory Commission (FERC) to streamline the process for merger analysis have focused primarily on this issue.[2] The FERC has proposed that market concentration measures be used as the foundation of a 'screening' process of proposed mergers.

However, many feel that traditional reliance on concentration measures is inadequate for the task. This is in part because concentration measures often depend upon historical data, such as energy sales and transmission congestion, which are of questionable value since the incentives of many firms will change significantly after restructuring. In part due to this weakness, the FERC has proposed substituting production-cost simulation results for historical data.[3] However, there is a fundamental flaw in modeling approaches that simulate markets as if they were perfectly competitive, and then apply generic measures of the potential for exercise of market power, such as concentration indices. The flaw results from the fact a firm or set of firms, through the very act of exercising market power, will usually alter their production patterns in ways that violate the assumption of market-wide least-cost production.

In place of concentration measures, researchers have begun to employ more sophisticated market analyses that attempt to capture the strategic aspects of competition in this industry.[4] These models are of course far from perfect. They do, however, offer several significant advantages over concentration analyses. One central insight from both theoretical and empirical models of restructured electricity markets is the phenomenon of markets separating into periods where there is very little market power and other periods in which the potential for market power is very high.[5] This separation occurs when demand rises above levels for which several producers can contest to supply that load. This separation is more pronounced in the electricity industry because of the relatively limited production capacities of small producers, the widespread potential for transmission congestion, and the fact that electricity is expensive to store. As we discuss below, these factors combine to make the elasticity of demand for electricity a crucial factor in determining the potential impacts of market power.

In this paper, we discuss some of the strengths and weaknesses of the market power models that have been applied to the electricity industry. In doing so, we illustrate some of the insights that can be gained from the use of game-theoretic models with examples taken from analyses we have performed on the California and New Jersey markets. Some of these examples build upon earlier models of the California electricity market.[6] In particular, we utilize a Cournot-Nash approach combined with a price-taking fringe to evaluate the 'threshold' demand levels at which these

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[2] See FERC (1998a).
[3] This is the approach that has been proposed in (FERC, 1998b).
[4] See Smeers (1997) for a discussion of the applicability of these models.
[5] von der Fehr and Harbord (1992) provide a theoretical underpinning for this phenomenon, and Wolak and Patrick (1996) provide empirical evidence of such a market separation in the United Kingdom.
[6] See Borenstein and Bushnell (1998)

markets transition from relatively competitive ones to ones in which market power is a potentially serious problem. This approach also facilitates analysis of the sensitivity of the results to such factors as transmission capacities and competitive entry.

2. Market Power Analysis

The fundamental measure of the exercise of market power is the price-cost margin,[7] which measures the degree to which prices exceed marginal costs. Prices above marginal cost lead to both inefficient allocations -- since consumption is too low in response to prices that are too high -- and potentially to inequitable transfers from consumers to producers. In most industries, analysts are unable to measure price-cost margins, because costs are usually the private information of the producers. Often concentration measures, such as the Hirschmann-Herfindahl Index (HHI), are used instead. The use of concentration measures as a proxy for the potential for market power has a long history. Governmental agencies concerned with market power, such as the Department of Justice, have long relied on projected changes in concentration measures to analyze the impact of structural changes in a market.

However, although industry concentration and individual firm market share are often correlated with market power, this is not always the case. There are many factors beyond the number and size of firms in a market that impact the degree of competition within an industry. These factors include:

- **The incentives of producers**: In the near term, it is likely that electricity markets will feature a diverse set of firms, including publicly owned utilities, unregulated generation companies, and traditional vertically integrated regulated utilities. Each type of firm is likely to respond differently to a given competitive environment.

- **The price-responsiveness (elasticity) of demand:** In markets where customers can easily choose not to consume a product, or to consume a substitute instead, producers cannot raise prices far above costs without significantly reducing sales. Conversely, a producer that knows that its product is absolutely needed can profitable raise prices to very high levels.

- **The short-run potential for entry into a market:** Just as a producer with very price responsive customers cannot exercise much market power, neither can a producer faced with many price-responsive competitors. Transmission capacity into a region and available competitive generation capacity are the main factors in determining the potential for short-run competitive entry.

These factors are not captured by measures of the concentration of an industry. Concentration measures indicate the current distribution of sales or capacity, but cannot tell you what will happen to prices when one firm reduces its output. This is a critical question in the electricity industry where the product is, with some exceptions, not storable and short-run demand is

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[7] The price-cost margin, often referred to as the Lerner index, is defined as $\frac{P - MC}{P}$.

relatively inelastic. Even though one firm may have a small market share at a given demand level, it may be the case that if that firm reduced output, no other firm would be able to replace that supply because of cost, capacity or transmission constraints. The Cournot-Nash algorithm, described below, helps to analyze and detect such situations.

2.1 Cournot-Nash Equilibrium Concept

The basis of our analysis is the Cournot-Nash Equilibrium concept. That is to say that we adopt the assumption that strategic players employ *quantity strategies*. In the context of an electricity market, the Cournot model seems an appropriate starting point, one that has been utilized in various forms to analyze electricity markets by Andersson and Bergman (1995), Oren (1997), and Hogan (1997). The other basic non-cooperative equilibrium concept, the Bertrand equilibrium, is supported by the assumption that any firm can capture the entire market by pricing below others and can expand output to meet such demand. Since generation capacities present significant constraints in electricity markets, this assumption is not tenable. Previous research suggests that if firms choose their capacities and then compete on price, within the restrictions of their capacity constraints, the outcome may be closely approximated by the Cournot model.[8]

Capacity constraints on generation are significant in both the medium-term – based upon investments in construction of new capacity – and the short-term, in which plants are rendered "unavailable" due to maintenance and other reliability considerations. This latter, short-term, constraint is most relevant to our work, because the capacity investments of the major players have already taken place.[9] In their study of the UK electricity market, Wolak and Patrick (1996) argue that the market power of the dominant firms is manifested through those firms declaring certain plants unavailable to supply in certain periods. Thus, the centralized price mechanism and capacity-constrained suppliers in electricity markets (at least during peak periods) support the use of a Cournot model for a base case analysis.

Other oligopoly equilibrium concepts

To date, we have primarily utilized the Cournot-Nash concept in our studies of electricity markets, and the examples we will draw on later come from Cournot analyses. There are, however, other equilibrium concepts that can be considered. It is difficult to point to a single economic equilibrium concept as the "best" approach for all markets. Each has strengths and weaknesses that make such a choice very much case specific. It is often the case that different models may produce different insights into potentially profitable strategic behavior. However, all of these insights can be of value to policy makers. As with any economic model, it is important to remember the implications of the model choice itself when interpreting its results.

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[8] See Kreps and Scheinkman (1983). See Davidson and Deneckere (1986) for discussion of the limits of this finding.

[9] There is one other significant short-term capacity constraint, involving the commitment of generation units to a dispatch process. Since most generation units are constrained on how quickly they can begin producing output from a shut down state and how quickly they can increase output to higher levels, generators must commit to certain output capabilities before they actual provide output in a given hour. We discuss the qualitative implications of these constraints on our market power model later in this paper.

One game-theoretic concept that has been prominently applied to electricity markets is the modeling of equilibria when bidders specify cost/quantity 'supply curves.'[10] One of the obvious attractions of a supply curve equilibrium model is that it seemingly represents the actual behavior of firms more accurately. The output of a supply-curve equilibrium model is an actual price-quantity bid curve, rather than the inflexible quantity bid given by the Cournot model. It is also important to note that supply-curve competition can produce results that are closer to the competitive outcome than those produced by the Cournot model.

However, the supply-curve model also has some weaknesses that may limit its usefulness when applied to certain electricity markets. In general, this approach produces multiple equilibria and the diversity of these equilibria grows as the uncertainty of demand is reduced.[11] The Cournot equilibrium represents an upper bound on supply function equilibria, thus it constitutes a reasonable screening measure of the potential for market power. The supply curve approach also does not lend itself well to markets where there is a competitive fringe whose capacity may be limited due to either generation or transmission constraints.[12] In the United States, as we will argue below, this is often a key factor in determining the competitive outlook for a given market.

Finally, neither the Cournot model nor the supply-curve approach addresses issues of collusion. In both of these models, it is assumed that any exercise of market power would be unilateral by each firm. The ability of a group of firms to collude will depend on many factors, including the level of concentration, the ease of new entry or output expansion by fringe firms, the frequency with which prices are set, the likelihood that the firms will meet again in the future, the ability of firms to monitor the behavior of rivals or potential collusive partners, and the homogeneity of cost attributes across firms. Unfortunately, economic models of collusion generally offer little practical guidance about diagnosing collusive exercise of market power. Thus, our analysis does not directly capture the potential for collusive outcomes.

3. Cournot–Nash Methodology

In this section we describe the modeling approach used for calculating the results presented in section 4. In general firms were divided into two categories, Cournot and price-taking fringe firms. Large deregulated generation companies were assumed to follow Cournot strategies, while firms that, either due to their size or regulatory status, were considered to be non-strategic, were combined into a single, price-taking fringe.

3.1 Market Demand

[10] See Green and Newbery (1992), Green (1996), and Rudkevich, et al. (1998), for examples of this approach.
[11] See Bolle (1992).
[12] This is due in part to the fact that, to date, supply curve models have relied upon the assumption that the slope of the demand function does not vary across time periods (or demand levels). The introduction of a significant price-taking fringe and of transmission constraints results in demand curves that are 'kinked' at the points at which these constraints become binding. The slope of demand is therefore not only changing as demand increases, but this change is endogenous to the output decisions of the strategic firms.

In almost every electricity market that we, or others, have examined there is little potential for market power in off-peak, low demand hours. In many markets, however, there is significant potential for market power during peak hours. This is due, in part, to the fact that when demand rises beyond a given level, both the transmission and generation capacity of potential competitors becomes exhausted, leaving the residual market to just a few dominant firms on the margin.

Because of this pervasive characteristic of competition in electricity markets, we examined a broad range of demand levels in the markets that we have studied. By a range of demand levels, we, in effect, mean a range of demand *curves*, since we assume that demand is at least somewhat price-responsive. Since most electricity customers today face a constant marginal price for electricity, we fix our demand curves to reference points that relate to currently observed or forecast price-quantity pairs. In other words, our demand curves are set so that the market demand, at current prices, would equal the current demand levels. Figure 1 illustrates the construction of the demand curves used in the simulations. The demand function D_1 is chosen such that at current prices, market demand would be 10,000 MW, while D_2 is defined such that market demand would be 25,000 MW at current prices. In the results presented below demand functions are identified by their “anchor” demand quantity (e.g. the anchor quantity of D_1 is 10,000). To account for the fluctuations between peak and off-peak demand, we vary this “anchor quantity,” while keeping the reference price the same.

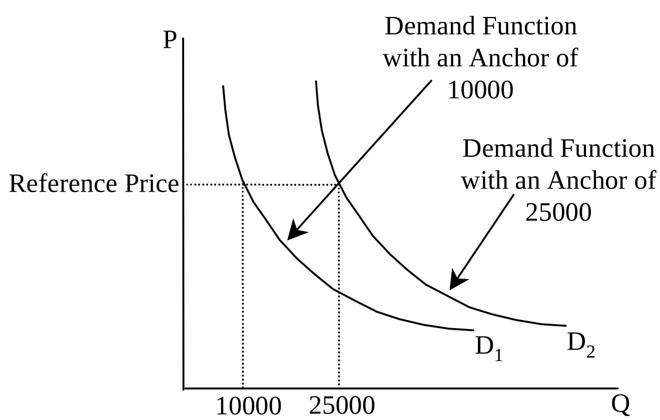

Figure 1 –- Simulation Demand Functions

3.2 Market Supply

The cost curves of the firms were constructed using plant level data on the capacities, heat rates, fuel and maintenance costs of each generation unit.[13] The capacity of each generation unit was ‘derated’ according to the forced outage rate of that unit, yielding an expected capacity. The cost-capacity pairs of each unit were then combined to produce, for each firm, a step-function of

13 For the California market, the results presented here assume that the hydro resources of each California firm are operating at its minimum flow level. This is approximately the condition that obtains in the late fall and early winter, when market power is most likely to be of concern. Hydro production is considered to be costless, and is represented as a zero-cost step in the cost function. Bushnell (1998) examines the potential market impacts of the strategic manipulation of hydro electric resources.

cost of total output.[14] Generation that will continue to operate under inflexible, non-market based agreements, such as some nuclear and independent power facilities, was also treated as price-taking and added to the fringe.

3.3 Cournot Algorithm

Treatment of Fringe Firms

To analyze competition among the Cournot firms in this market, we first control for the effect of the fringe by subtracting the aggregate supply of these firms from the market demand. From this, we obtain a residual demand curve that the Cournot firms in the market would face. To obtain the aggregate fringe supply at any given price, we add together the quantity that each of the price-taking firms would produce if it produced every unit of output for which its marginal cost was less than the price. Fringe generation units operating outside of the analyzed market face the additional constraint that their exports into the market cannot exceed the respective transmission limits. We then subtract the quantity that would be supplied by the fringe firms at every price from the market demand quantity at that price yielding a residual demand quantity at that price. The Cournot firms compete over this resulting residual demand function which is more price elastic than the original market demand function. Formally, the demand function faced by the Cournot firms is represented as:

$$D_r(P) = D(P) - \sum Min(S_i^f(P), TR_i) \qquad \textbf{(1)}$$

where $D(P)$ is the market demand function, S_i^f represents the fringe supply curves for fringe firm i and TR_i represents the transmission constraint faced by the ith fringe firm. Thus the supply capability of the fringe can be constrained by transmission limits. The function, $D_r(P)$ is the resulting residual demand curve faced by Cournot players in their respective markets.

Cournot Firms

To analyze the behavior of the Cournot firms, we have compiled data on the marginal cost and capacities of the firms. In addition, using the above definition of the residual demand curve we construct the residual demand curve faced by the Cournot players for a wide range of market demand levels. The use of these demand ranges allows us to accurately pinpoint demand levels where market power problems are likely to exist. For each demand level, we calculate the Cournot equilibrium iteratively. Using a grid-search method, we determine the profit-maximizing output for each Cournot supplier under the assumption that the production of the other Cournot suppliers is fixed. This is repeated for each Cournot firm: the first supplier sets output under the assumption that the other Cournot players will have no output, the second sets output assuming the first will maintain its output at the level that was calculated for it in the previous iteration, and so on. The process repeats, returning to each supplier with each resetting its output levels based upon the most recent output decisions of the others, until no supplier can profit from changing its output levels given the output of the other Cournot suppliers. Thus, at the Cournot

[14] This process is described in more detail in Borenstein and Bushnell (1998).

equilibrium, each firm is producing its profit-maximizing quantity given the quantities that are being produced by all other Cournot participants in the market.

At each iteration, every Cournot player faces a demand function that is the residual demand curve in equation (1) above minus the production quantities of all other Cournot players. Therefore, although the market demand curve is a constant elasticity demand curve with elasticity less than one, which would cause a monopolist to charge an infinite price, no one firm faces that demand curve, insuring a finite price. More formally, every Cournot player *i*, faces demand

$$D_i(P) = D_r(P) - \sum_{k \neq i} D_k \qquad \textbf{(2)}$$

where *k* indexes firms that are Cournot players and $D_r(P)$ is the residual demand curve defined in (1). This demand will in general be much more elastic than *D(P)* at every price.[15]

Multiple Equilibria

One drawback of our treatment of the price-taking fringe is that the residual demand, being *D*(*P*) minus the fringe supply, can contain flat regions. This results from the fact that each plant is assumed to have a constant marginal cost up to capacity, causing the fringe supply curve to have flat regions. As a result, the demand curve faced by any one firm will also have flat regions and those flat regions will be associated with discontinuities in the marginal revenue curve that the firm faces. For a given firm, this can result in multiple local profit maxima. This in itself is not a problem since our grid-search method assures that the output derived is a firm's global profit maximum. However, this can also lead to multiple equilibria since small changes in the output of other firms can cause a given firm to make relatively large jumps in its own output.

The reader should keep in mind that the results reported here present one of potentially several equilibria. However, it is almost certain that the equilibrium with higher prices is the most profitable for each strategic firm. In a repeated market such as this one, it is reasonable to expect that firms would move towards the most profitable equilibrium point. Our past experience with other simulations lead us to believe that the equilibria reported here are the ones with the highest prices of any multiple equilibria that may exist.

3.4 Sensitivity Analysis

It is important to remember that this model, like any quantitative simulation of competition between firms, is a stylized representation of both the capabilities and behavior of the firms involved. By evaluating the potential for market power over a broad range of potential demand levels, we can estimate the sensitivity of these results to factors not directly represented in the model and to changes in some of the model parameters. The impact of many of these factors can

[15] Although a constant-elasticity demand function with elasticity less than one would yield an infinite price for a monopolist, equilibrium price will always be finite if there is positive output from a price taking fringe. To see that this is the case, note that with positive output from the price taking fringe, the residual demand faced by Cournot firms in a market will, at a sufficiently high price, always intersect the vertical axis.

be roughly approximated by adjusting the levels of native demand. In this section, we summarize some of these factors and their likely impact on market power.

Reserve Margins

The impact of the needs for reserves can be approximated by adjusting the demand upwards by the reserve percentage. This would apply to the demand curve's baseline or "anchor point" demand. Therefore, when interpreting the Cournot equilibrium results presented in the following sections, one would simply adjust this baseline demand. To approximate the impact of a 10% reserve margin on an hour when baseline demand is 10,000 MW, one would simply use the results when baseline demand, without reserve, is 11,000 MW.

Pump Storage and New Entry

The addition of inexpensive fringe capacity can be closely approximated by shifting the demand curve downward by an amount equivalent to the new capacity. Thus the "residual" demand seen by the Cournot firms has been reduced by the addition of fringe production. The same logic would apply towards the utilization of pump-storage capabilities *by fringe players*. The storage units would in effect add generation capacity to high demand hours, when prices are at their highest.

The impact of the addition of new storage or conventional generation capacity by Cournot players is more difficult to approximate. In the hands of a very dominant firm, the extra capacity may have little impact, since that firm would presumably be reducing the output from the units it already has. New capacity in the hands of a smaller Cournot player would probably decrease the extent of market power, although by less than if that capacity were owned by a fringe player.

Transmission Capacities and Losses

The effects of transmission losses and the capacities of the lines can sometimes also be approximated by shifts in demand when the outside markets are assumed to be competitive, as they are here. The same logic applies for an increase in the transmission capacity to markets *where there is abundant and inexpensive excess capacity*. However, it is important to remember that the expansion of transmission capacity into markets where there is little surplus generation capacity will have little impact on competition.

4. Results of Analysis of US Markets

In this section we provide examples of how an equilibrium analysis can yield insights into the competitive nature of markets beyond those provided by concentration indices. These examples build upon studies we have performed on electricity markets in the U.S.[16] They make clear that the potential for market power depends heavily on the amount of demand in a given market.

[16] For a complete description of the data and methodology used see Borenstein and Bushnell (1998) and Borenstein, Bushnell, and Knittel (1998).

Fringe production capacity, demand elasticity, and transmission capacity also play key roles in the competitiveness of our simulated markets.

Production Capacity of Non-Strategic Producers

A brief examination of the California electricity market reveals a market with a diverse set of producers. California is home to a large amount of non-utility generation, using both fossil-based and renewable fuel technologies. Furthermore, there are several municipal utilities of various sizes, including the Los Angeles Department of Water and Power, the third largest producer in the state. When one also considers imports into the state from other regional markets, such as the Pacific Northwest and the desert southwest, this market indeed appears quite *unconcentrated* by traditional standards.

However, we found that under generation ownership that existed in 1997 there would be a significant potential for market power in hours with high demands. At higher demand levels, many producers reach their full output capacities. The disciplining effect of those producers on strategic behavior by the remaining firms therefore is severely reduced. These remaining producers can profitably reduce their output, knowing that most of their capacity-constrained competitors will be unable to respond with increased production. Ironically, when such behavior occurs, the concentration of the market appears to be reduced, since the strategic firms – the largest producers – are in fact withholding production, and therefore reducing their market share. We found many cases in which the price-cost margin increased as concentration declined.

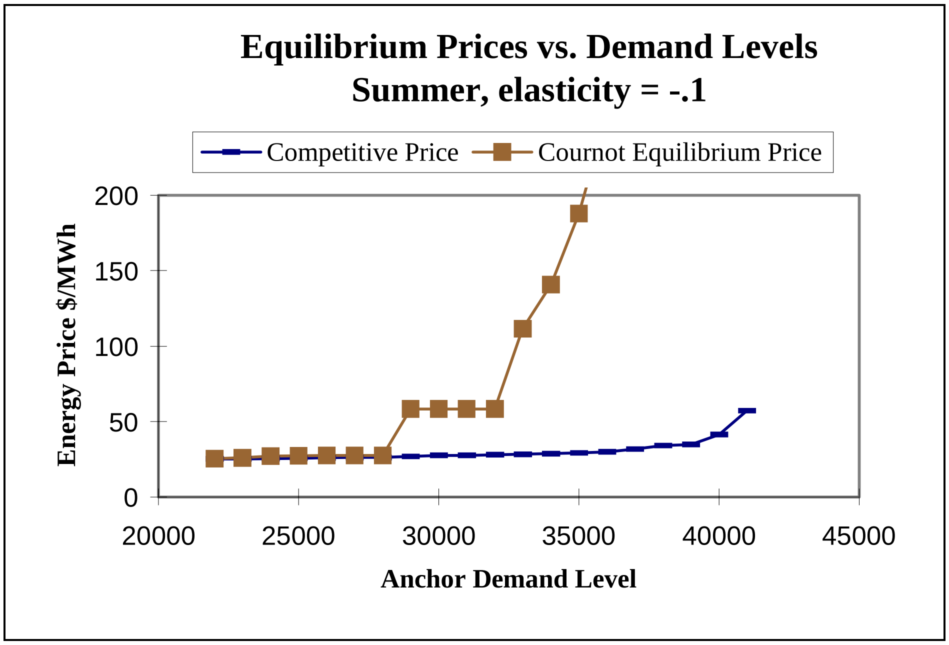

Figure 2— California Cournot Prices Relative to Perfect Competition

Figure 2 illustrates this point. On the horizontal axis we plot the "anchor quantity" of our demand curves. In other words, the demand in the market if prices were equal to those today.[17] The final market demand from our simulations varied from these levels as the Cournot equilibrium prices were sometimes far higher than current prices. In Figure 2 we plot the perfectly competitive price along with the Cournot equilibrium price for "anchor demands" ranging from 21,000 MW to 42,000. The Cournot price closely tracks the perfectly competitive price at low demand levels and then rises sharply beyond a certain threshold level, around 27,000 MW. Prices at this point begin to rise because an increasing number of competitive firms reach their maximum capacity. The two largest firms, Pacific Gas & Electric (PG&E) and Southern California Edison (SCE), then find it profitable to reduce their output and drive up prices. The resulting effect on concentration is that the market appears most concentrated at demand levels where these two firms are not trying to reduce output and, thus, markups are low. This is demonstrated in Figure 3, where the HHI and the Lerner index of markups are both plotted over different anchor demand levels. The Lerner index, defined as (P-MC)/P, ranges from zero when price is equal to marginal cost to near one when marginal cost is a vanishing proportion of the price charged to consumers.

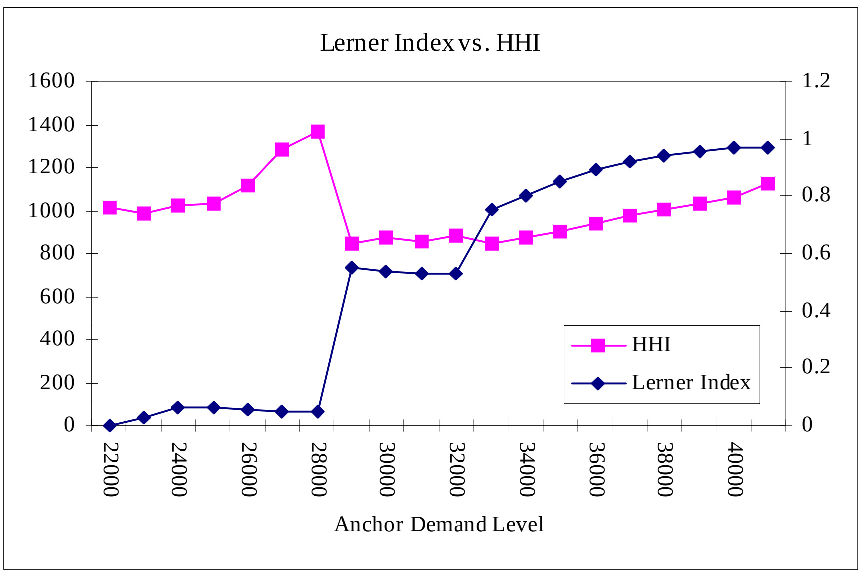

Figure 3 –- Lerner Index versus HHI Index

California divestitures of generation plants

Originally, the two largest investor owned utilities in California, Pacific Gas and Electric (PG&E) and Southern California Edison (SCE), were pressed to divest one-half of their gas-fired generation capacity. Although this original divestiture[18] did have a significant impact on the equilibrium prices in our model, the potential for substantial market power still remain.

[17] For our study of California, our reference price was based upon a forecast by the California Energy Commission of the statewide average price in the year 2000. This price was 9.3 cents/kWh.

[18] In this case, each set of units was divided into roughly equal lots. This created one additional northern Californian firm out of half of PG&E's gas generation and two additional southern Californian firms, each controlling roughly half of SCE's current gas generation capacity. These new firms were assumed to be Cournot players.

Eventually, both PG&E and SCE announced plans to sell off *all* of their gas-fired generation. Most of these transactions have been negotiated, with the transfer of ownership of most of these plants to occur during the next year. As Table 1 indicates, the generation capacity of these two formerly dominant firms will soon be divided into 8 highly decentralized generation portfolios. The impact of these additional divestitures on equilibrium prices is significant. Figure 4 presents the equilibrium prices under the originally proposed divestiture as well as the actual divestiture. The results illustrate that the current divestiture proposal is likely to have a far greater impact on equilibrium prices in the California market than the original proposal. Although, there still remain demand levels where market power can be a problem, the threshold value where this is likely to occur is far greater under the current divestiture plan, relative to the original proposal.

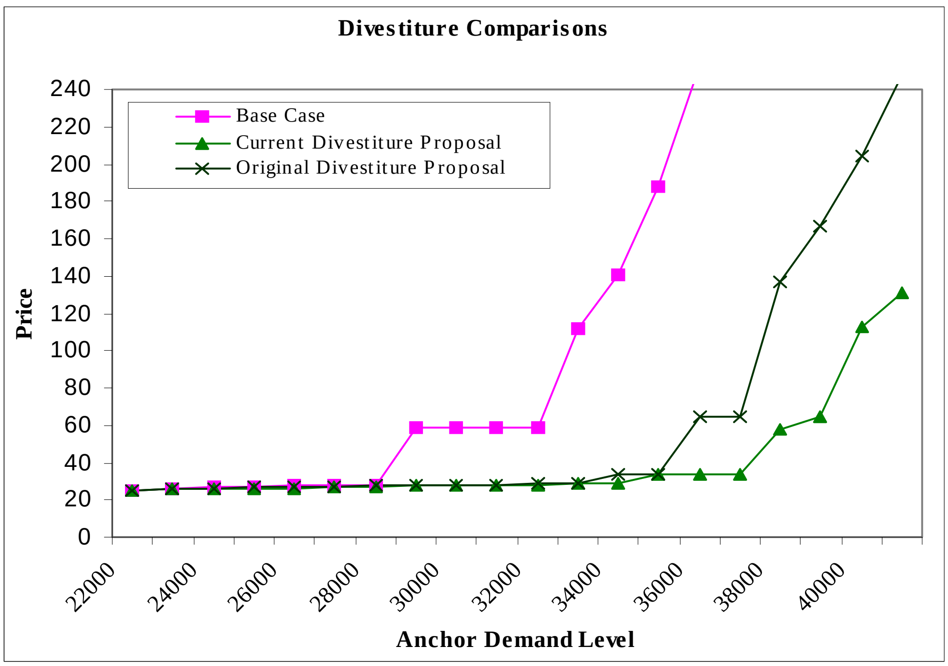

Figure 4 — The Impact of Proposed Mergers

Table 1 — Pre and Post Divestiture California Thermal Capacity

	Pre Divestiture (MW)	Post Divestiture (MW)
PGE	8083	782
SCE	12314	1378
New Firms		
CFE		1379
Duke		2306
AES		3705
Houston		3554
NRG		1445
TCK		249
unknown		3093

The Impact of Demand Elasticity

One of the reasons that extreme price mark-ups can be sustained at demand levels where fringe capacity is constrained is that demand for electricity currently is not very price responsive. When this is the case, a larger firm may be able to increase profit by unilaterally decreasing its output since output reductions have a substantial impact on price. Such reductions lead to higher retail rates and social losses. In contrast, if the amount of electricity demanded is responsive to changes in price, then reductions in output by a single firm lead to small price increases and therefore a loss of profit. Only if firms are able effectively to collude in joint output reductions is price likely to be substantially above cost when demand is highly elastic.

Indeed, our analyses of the California and New Jersey markets confirm the importance of the elasticity when exploring the likelihood of market power in a restructured electricity industry. The policy implications from these results are clear. Policies that make consumers more responsive to real time prices can have dramatic effects on equilibrium prices and may be more effective than more traditional policies designed to combat market power, such as increases in transmission limits and generation capacity. This point is highlighted in Figure 4, which illustrates the equilibrium prices found in a restructured California market under three alternative scenarios; a demand elasticity of 0.1 with the current ownership of assets, a demand elasticity of 0.1 under the forthcoming divestiture of PG&E and Southern California Edison gas units, treating the newly created firms as Cournot players, and a demand elasticity of 0.4 with the current ownership of assets. The results illustrate that increasing the elasticity of demand from 0.1 to a still relatively inelastic level of 0.4 produces substantial decreases in prices. At high demand levels, the price reductions are greater even than those under divestiture.

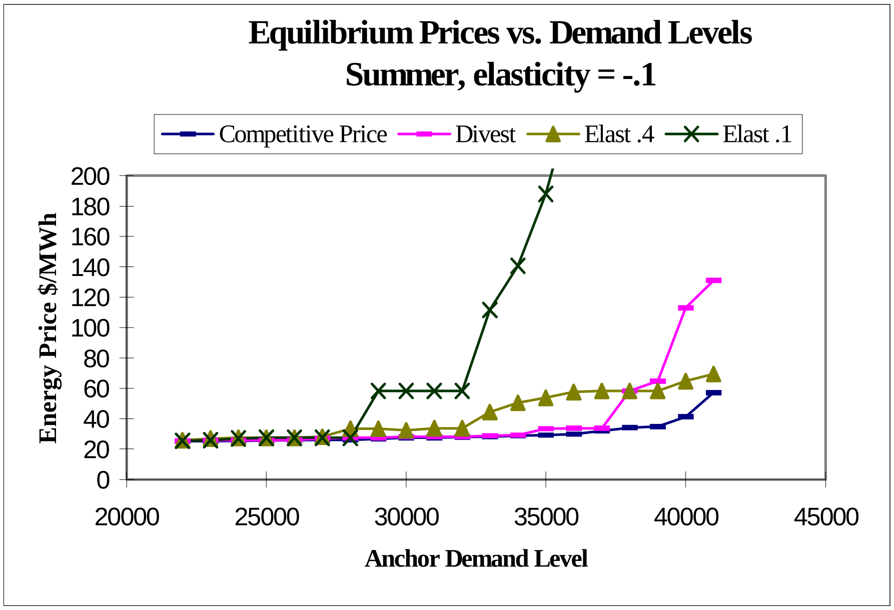

Figure 5 — The Impact of an Increase in the Responsiveness of Demand

The Potential for Strategic Use of Transmission Constraints

We have demonstrated in our work that limits in transmission capacity can have important impacts on the level of competition in certain markets by restricting the potential short-term entry into a given market. It is important to note that this effect is likely to occur much more frequently in deregulated markets. Some strategic firms, knowing that the scope of imports is limited by transmission constraints can profitably restrict output, thereby increasing imports and congestion on transmission paths into the strategic firm's region. Conversely, increasing transmission capacity into a region can have strikingly large impacts on the competitive health of that region.

Some examples from a preliminary study that we have made of the electricity market in New Jersey help illustrate this point. The eastern portion of the PJM (Pennsylvania, Maryland and New Jersey) pool at times constitutes a load pocket. An examination of historical congestion patterns[19] reveals that the transmission flows between the western and eastern portions of the pool have seldom reached the limits of that path. Flows along this path, however, have been within 500 MW of these limits far more often. This indicates that firms that own generation within the eastern portion of the pool might be able to profit from reducing output slightly and inducing congestion along this path.

[19] See Joskow and Frame (1997).

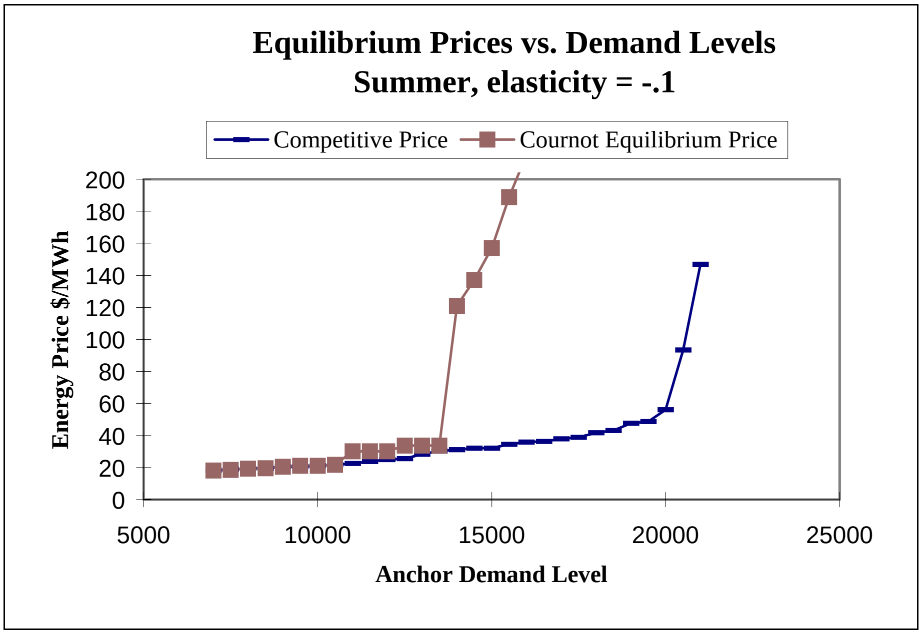

Figure 6 — PJM-East Cournot and Competitive Prices, Summer Costs and Capacities

Our Cournot equilibrium analysis indicates that, at high demand levels, this is the case. We again examined a broad range of demand levels by varying the "anchor quantities" of the demand curves used in our equilibrium calculations. As with the California market, we find that there is almost no market power at low demand levels, and that Cournot equilibrium prices rise steeply with demand above a certain threshold level. Figure 5 illustrates our results for a demand elasticity of 0.1.[20] The divergence of competitive and Cournot equilibrium prices are closely related to the level of congestion along the PJM west-to-east interface. Indeed, a comparison of the west-to-east flows under the assumption of perfect competition with those that arise when firms in the east act as Cournot competitors (Figure 7) reveals that the occurrence of congestion greatly increases when firms in the east act strategically.

[20] In calculating these equilibria, we assumed that generation units located in the western portion of the PJM pool, including those owned by firms located primarily in the east, would be dispatched non-strategically. The study is described in detail in Borenstein, Bushnell, and Knittel (1998).

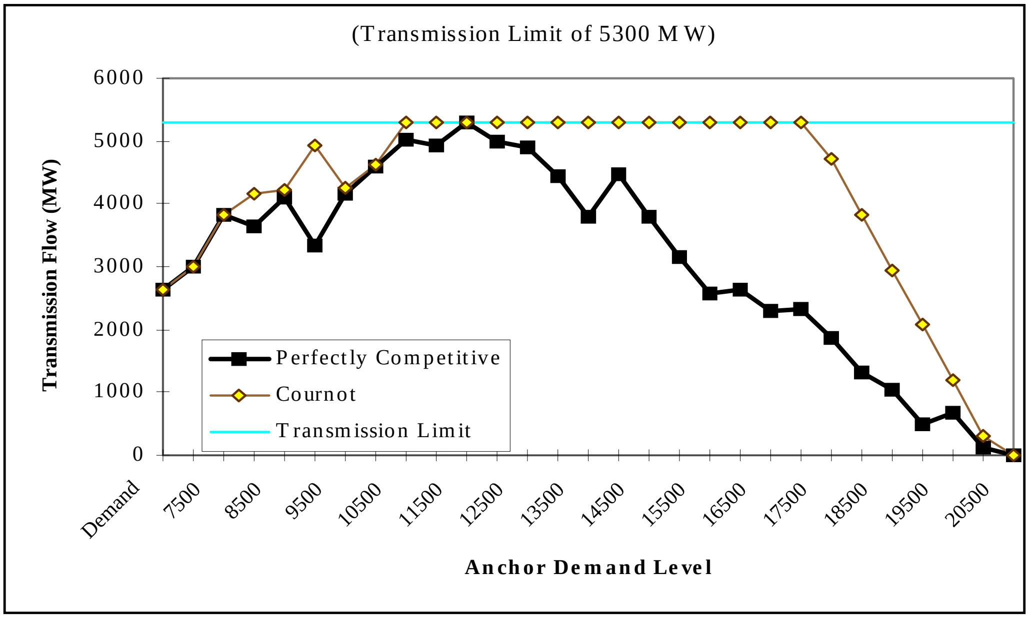

Figure 7— PJM West to East Transmission Flows

5. Conclusions

The current move by governments to restructure electricity markets -- allowing the competitive interactions among many buyers and sellers to set price -- has spurred research into the likelihood of market power in electricity markets. Policy makers need to estimate the ability of firms to sustain prices above competitive levels. In the past, because of the proprietary nature of cost information in most industries, such estimates have relied on concentration measures. Concentration measures, however, suffer from a number of weaknesses, which are exacerbated when applied to restructured electricity markets. This paper has highlighted some of the more important shortcomings, such as reliance on regulation-era market share data and failure to account for either demand elasticities or the costs of different generating plants. The use of data, either historic or derived from simulation, that is based upon an assumption of least-cost dispatch can greatly overstate the geographic scope of markets and therefore the competitiveness of a market.

We have highlighted the results from our previous studies that employ an alternative method for estimating the potential for market power in an electricity market. Our work has taken actual cost, demand, and transmission capacity data into account when employing a Cournot–Nash equilibrium model of the electricity market. In this paper, we have discussed some of the strengths and weaknesses of the market power models that have been applied to the electricity industry. While the Cournot-Nash model is far from perfect -- it ignores, for instance, the dynamic aspects of competition – it offers several significant advantages over concentration analyses.

The results of our analysis of two major U.S. regions indicates that during high demand hours, when fringe supply has reached its limit and large players in the market are able strategically to congest transmission lines, market power is indeed a concern. The process of divestiture of generation resources that is currently underway in California appears to significantly reduce the potential for market power in that region. In addition, the results suggest that market power is much more prevalent when demand is modeled as less responsive to price changes.

A number of policy implications emerge from these analyses. Our results indicate that policies that promote the responsiveness of both consumers and producers of electricity to short-run price fluctuations can have a significant effect on reducing the market power problem. In addition, the results suggest that transmission capacity investments may have disproportionate impacts on the price faced by consumers. Indeed, such policies may be yield greater benefits, and be less contentious, than other approaches that attempt to regulate prices under various conditions.

The results presented in this paper, although suggestive that the equilibrium prices in a restructured market are likely to diverge from those under a perfectly competitive market, should not be seen as suggesting that deregulation is a mistake. Few markets are completely devoid of market power, if any. Therefore, the relevant comparison is not to the efficiency of a perfectly competitive regime, but rather to efficiency under the current, regulated structure.

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